GEOLOGY AND GEOPHYSICS

Karina Zavala, a Johns Hopkins graduate student, breaks up a sample of igneous rock from the Dry Valleys. Her group, led by Bruce Marsh, brought more than 1,000 pounds of rocks back to the states from Antarctica. *(NSF photo by Josh Landis)*

Antarctica is not only one of the world's seven continents, but also comprises most of one of its dozen major crustal plates, accounting for about nine percent of the Earth's continental (lithospheric) crust. Very little of this land is visible however, covered as it is by the vast East Antarctic Ice Sheet and the smaller West Antarctic Ice Sheet. The ice sheets average some 3 kilometers deep - a virtual vault, 90 percent of the ice on Earth is here. And it is heavy, depressing the crust beneath it some 600 meters (m). These physical characteristics, while not static, are current. Yet thanks to the sciences of geology and geophysics, powered by modern instruments and informed by the paradigm of plate tectonics/continental drift, Antarctica is also a time machine.

Geologists have found evidence that there was once a forested supercontinent in the Southern Hemisphere, which they call Gondwanaland. Before the Earth's constantly shifting plate movement began to break it up 150 million years ago, Antarctica was a core piece of this assembly; its adjoining land has since become Africa, Madagascar, India, Australia and South America. Though the Antarctic Plate has drifted south only about a centimeter each year, geologic time eventually yields cataclysmic results. The journey moved it into ever colder, high-latitude climates, at a rate of about 4°C for each million years; eventually life conditions had changed dramatically, and Antarctica arrived at a near polar position. This stounding story - written in a language of rock and fossils - is locked in and beneath the ice, the sea, and in the bedrock below both.

As the ice sheets developed, they assumed what has become a key role in modulating global climate, through their interaction with oceanic and atmospheric circulation. As a bonus, the South Pole also presents a strategic point to monitor the Earth's current seismic activity. Antarctica is the highest continent on Earth (about 2,150 m above sea level), with its fair share of mountains and volcanoes; thus many generic questions of interest to Earth scientists worldwide also apply to this region. Some specific issues focused on by the Geology and Geophysics program include:

• determining the tectonic evolution of Antarctica and its relationship to the evolution of the continents from Precambrian time (600 million years ago) to the present;

• determining Antarctica's crustal structure;

• determining how the dispersal of antarctic continental fragments may have affected the paleocirculation of the world oceans, the evolution of life, and the global climate (from prehistoric times to the present);

• reconstructing a more detailed history of the ice sheets, identifying geological controls to ice sheet behavior, and defining geological responses to the ice sheets on regional and global scales; and

• determining the evolution of sedimentary basins within the continent and along continental margins.

All of these problems will be simplified as scientists improve their models of where, when, and how crustal plate movement wrought Antarctica and its surrounding ocean basins. The Geology and Geophysics program funds investigation into the relationships between the geological evolution of the antarctic plate and the life and processes that can be deduced to accompany it - paleocirculation of the world ocean, paleoclimate of the Earth, and the evolution of high-latitude biota. A current emphasis is the West Antarctic Ice Sheet Program (WAIS), research focused on the smaller of the continent's two ice sheets, conducted also under the aegis of the Glaciology program. Several important research support activities are also underway:

• **Meteorites:** In a partnership with NASA and the Smithsonian Institution, the program supports meteorite collection through the Antarctic Search for Meteorites (ANSMET) and chairs an interagency committee that is responsible for curating and distributing samples of the antarctic meteorites.

• **Mapping and geodesy:** In partnership with the U.S. Geological Survey (USGS), the program supports mapping and geodetic activities as an investment for future research in earth sciences. The U.S. Antarctic Resources Center (US-ARC) constitutes the USAP contribution to the Scientific Committee on Antarctic Research (SCAR) library system for earth sciences information; housed here is the largest collection of antarctic aerial photographs in the world, as well as many maps, satellite images, and a storehouse of geodetic information.

• **Marine sediment and geological drill cores:** In a partnership with the Antarctic Marine Geology Research Facilty at Florida State University, the program manages and disseminates marine sediment and geological drill cores mined in Antarctica. The collection includes an array of sediment cores as well as geological drill cores from the Dry Valley Drilling Project, the CIROS drilling program, and the Cape Roberts Drilling Project. The facility fills requests for samples from researchers worldwide, and also accommodates visiting researchers working on site.

Global positioning system measurement of isostatic rebound and tectonic deformation in Marie Byrd Land, West Antarctica.
Bruce Luyendyk, University of California at Santa Barbara.

The Ross embayment and western Marie Byrd Land are part of the west antarctic rift system. Most scientists agree that this region is undergoing active deformation, but the rates and causes of deformation remain essentially unknown. Tectonic extension may be occurring in the Ross embayment as West and East Antarctica continue to separate. Or, crustal uplift could be occurring in western Marie Byrd Land due to isostatic rebound following the last glacial age.

If tectonic extension is occurring in the embayment - depending on its magnitude - it could greatly influence global plate circuit calculations. It could also constrain our understanding of the history of extension in the embayment and the consequent uplift history of the Transantarctic Mountains. Postglacial rebound in western Marie Byrd Land would depend on when and how the ice sheet was configured during the Last Glacial Maximum. The big question is whether the ice sheet collapsed in mid-Holocene time.

For this study we have installed three continuous and autonomous global positioning system (GPS) stations on outcrops in western Marie Byrd Land, on baselines of around 100 kilometers. These stations will gather data over 4 years (beginning during the 2000-2001 austral summer) and operate in concert with GPS stations being installed in the Transantarctic Mountains in a separate project; the result will be a baseline array deployed all across the Ross embayment. The array will also detect strain gradients in western Marie Byrd Land. This system should determine crustal strain rates to an accuracy of 1 millimeter (mm) per year for horizontal, and 2 mm per year for vertical. The strain data from western Marie Byrd Land and the Transantarctic Mountains should enable us to construct both tectonic extension and glacial rebound models.

This is a joint project between the University of California at Santa Barbara scientists and a team at the Jet Propulsion Laboratory at the California Institute of Technology.(GF-121-O)

Antarctic Mapping and Geodesy.
Jerry L Mullins and Richard E Witmer, U.S. Geological Survey.

Geodetic surveying, aerial photography, remote sensing (principally using several varieties of satellite imagery), and mapping are all activities necessary for the successful operation of a multifaceted scientific and exploration effort in Antarctica. The U.S. Geological Survey provides these support activities to the U.S. Antarctic Research Program.

Year-round data acquisition, cataloging, and data dissemination activities will continue in the U.S. Antarctic Resource Center for geospatial information. Field surveys will be conducted in support of specific research projects, and as part of a continuing program to collect the ground-control data necessary to transform existing geodetic data to an earth-centered system suitable for future satellite mapping programs.

LandSat data will be collected as part of satellite image mapping activities; this will permit continued publication of additional 1:50,000 scale topographic maps in the McMurdo Dry Valleys region. Such topographic studies provide a uniform base map on which to ensure that scientific information (from geology, glaciology, biology and other areas) is spatially accurate. These, as well as the satellite image maps, are used by scientists to plan and execute future research work. Spatially-referenced, digital cartographic data will be produced in tandem with the published maps.

Further, in the austral summer of 2001-2002, we will collaborate with the National Aeronautics and Space Administration Airborne Topographic Mapper Program to collect very high-resolution elevation data in portions of the McMurdo Dry Valleys and vicinity. The detailed land surface characterizations will be tested for feature recognition in the Beacon Valley, glacier studies in the Taylor Valley, and geologic applications in the Mt. Discovery area. The data will be tested for positional accuracy and resampled to provide regularly spaced observations for use in models and science. The USGS team will work with selected scientists to develop elevation data at resolutions that best serve their research needs. The data will then be used to develop elevation models at a variety of resolutions, as appropriate.

Very high-resolution data also will be collected for use by the ICESat research community to calibrate their 70-meter elevation data in Antarctica. The McMurdo Dry Valleys comprise a primary site for calibration and validation of NASA's ICESat satellite, scheduled for launch in December 2001. The primary sensor on ICESat is a laser altimeter, designed to measure the surface elevation very precisely, within the 70-meter footprint of the laser.

Because the altimeter will be operated with off-nadir pointing, it is equally important to calibrate for mounting angle as well as for range. A calibration site for such a sensor requires precise knowledge of local topography, which must be a stable, snow-free surface region with minimal vegetation. Angle calibration is also enhanced if you have variable surface slopes of moderately large amplitude (10-20 degrees).

With accurately measured surface elevations, the Dry Valleys provide a nearly ideal calibration site for ICESat. Furthermore, the Dry Valleys are in the region of the maximum altitude for the orbit of ICESat, allowing measurement errors to be detected through comparisons with measurements from other parts of the world. No other site in the world can provide this unique combination of features. (GO-052-L, GO-052-M, GO-052-P & GO-052-S)

Stability of land surfaces in the McMurdo Dry Valleys: Insights based on the dynamics of subsurface ice and sand-wedge polygons.
Bernard Hallet, University of Washington.

The dynamic nature of climate has received more public attention, as concerns grow about warming and the recent occurrence of seemingly extreme weather events. In this context, understanding the inherent variability of Earth's climate - how humans can and do affect Earth's environment - is becoming increasingly important. This project focuses on the landscape features and soils of Antarctica's dry valley region to provide a more complete understanding of past climatic and environmental conditions.

One important means of improving our understanding of the planetary climate system is to examine its past behavior, using the Earth as a natural laboratory. One of the most extreme changes in the climate system during the last few million years was the transition from a warm period in the Pliocene to an ice-age world. Scientists believe that during this interval relatively mild conditions in Antarctica gave way rapidly to intense glacial conditions, catalyzing the growth of what has become the largest ice sheet on Earth. This inference is based on geologic indicators of past climate, from which some scientists suggest that East Antarctica was relatively warm and largely free of glaciers about 3 to 4 million years ago (during parts of the Pliocene). The mild conditions ended abruptly, with rapid ice-sheet growth and development of the very cold, dry climate that now characterizes this region. A contrasting view, based on substantial geologic evidence, suggests that East Antarctica has been cold and the ice sheet stable for at least 8 million years, and perhaps considerably longer. These views lead to drastically different interpretations of the stability of Earth's climate.

We hope our research will help resolve this important dilemma by introducing independent new evidence and insights derived from studies of the stability of ground ice and land surfaces in the McMurdo Dry Valleys of Antarctica. We will study modern-day processes that have important implications for understanding the occurrence of buried ice found recently in Beacon Valley. This specimen may be the oldest ice on Earth; if so, it will provide strong evidence of long-term stability of the East Antarctic Ice Sheet, and may also afford a rare glimpse into atmospheric conditions millions of years ago.

Specific processes to be investigated include:

• exchange at the ground surface that affects ground temperature;

• water-vapor transport and other processes leading to the formation or loss of ice in the soil; and

• frost cracking due to contraction during rapid cooling of the frozen ground in the winter, and resulting disruptions of the soil. (GO-053-O)

ANSMET (the Antarctic Search for Meteorites).
Ralph Harvey, Case Western Reserve University.

Since 1976, ANSMET (the Antarctic Search for Meteorites program) has recovered more than 10,000 meteorite specimens from locations along the Transantarctic Mountains. Antarctica is the world's premier meteorite hunting ground for two reasons.

• First, although meteorites fall all over the globe at random, the likelihood of finding a meteorite is enhanced if the background material is plain and the accumulation rate of terrestrial sediment is low; this makes the East Antarctic Ice Sheet the perfect medium.

• Second, along the margins of the sheet, ice flow is sometimes blocked by mountains, nunataks, and other obstructions; this exposes slow-moving or stagnant ice to the fierce katabatic winds, which can deflate the ice surface and expose a lag deposit of meteorites (a representative portion of those that were sprinkled throughout the volume of ice lost to the wind). When such a process continues for millenia, a spectacular concentration of meteorites can be unveiled.

It is important to continue recovering antarctic meteorites because they are the only currently available source of new, non-microscopic extraterrestrial material. As such, they provide essential "ground truth" about the composition of asteroids, planets, and other bodies of our solar system. ANSMET recovers samples from the asteroids, the Moon and Mars for a tiny fraction of the cost of returning samples directly from these bodies.

During the 2001-2002 field season, ANSMET's main field party will visit the Meteorite Hills region near the headwaters of the Darwin Glacier. Systematic searching at this site began last season, when 740 meteorite specimens were recovered. This season will extend systematic searches to regions visited only sporadically last year. Two members of this field party will visit the nearby Finger Ridges icefield to further explore that meteorite-find site, where 3 meteorites were recovered in 2000-2001. A second field party dedicated to high level reconnaissance may be deployed to several icefields immediately south of the Beardmore Glacier. (GO-058-O)

Tracking the West Antarctic rift flank.
Paul Fitzgerald and Suzanne L. Baldwin, Syracuse University.

Reconstructing the motion of the Earth's crustal plates throughout geologic time is rarely as simple as looking at a blueprint. Geological evidence often suggests conflicting narratives, and newly developing techniques often provide critical information to further resolve the puzzle. The timing and mechanisms for the formation of the rift system in West Antarctica and the Transantarctic Mountains is illustrative.

The western side of the West Antarctic rift system extends along the Transantarctic Mountains and then into West Antarctica, along the northwestern flank of the Ellsworth-Whitmore Mountains crustal block. However, the rift flank is expressed quite differently along the Transantarctic Mountains than it is in West Antarctica. When did the rift and its associated rift flank form?

Some scientists have suggested a significant component of uplift as responsible for much of the relief of the rift flank in the last few million years. However, fission track data from the Ellsworth-Whitmore Mountains crustal block indicates that although most of the erosion exposing the rock strata (denudation) occurred there in Late Jurassic/Early Cretaceous times, a significant component of denudation is permissible in the Cenozoic. In contrast, most of the rock uplift and denudation in the Transantarctic Mountains occurred in the Cenozoic. We hope to shed some light on this controversy by determining the timing of uplift and denudation at key localities to allow us to determine the patterns of uplift and denudation along the West Antarctic rift shoulder.

Our objectives are:

• to determine the extent and timing of denudation of the West Antarctic rift flank;

• to further delineate patterns of uplift and denudation along the length of the Transantarctic Mountains;

• to document the thermal history of basement rocks from different crustal blocks; and

• to compare and contrast the thermal histories of East Antarctica (Transantarctic Mountains) and West Antarctica (Ellsworth-Whitmore Mountains crustal block).

We plan to use thermochronologic techniques for this work, specifically apatite fission track thermochronology and 40Ar/39Ar thermochronology. All laboratory work will be undertaken at Syracuse University. Data that integrates both fission track and 40Ar/39Ar thermochronology should produce a better understanding of the geological evolution of the continent.

We know that the Transantarctic Mountains were largely created during the Cenozoic. But then why didn't a large rift-flank mountain range arise in West Antarctica? Most of the West Antarctica rift system is buried under floating ice shelves or the West Antarctic ice sheet and its history is poorly known. If we can specify the uplift and denudation history, as well as the tectonic evolution of the rift flank, we will be able to further constrain the history of the rift zone itself. (GO-059-O)

Evolution and biogeography of Late Cretaceous vertebrates from the James Ross Basin, Antarctic Peninsula.

Judd Case, St. Mary's College and James E. Martin, South Dakota School of Mines and Technology.

The study of evolution has always been driven by the surprising appearance of fossils and species in disparate areas of the world. An example is the James Ross Basin along the eastern Antarctic Peninsula region. Paleontologists have found fossils that paint a vivid picture of vertebrate biogeography (that is, dispersals and separations due to moving landmasses) from about 80 to about 65 million years ago. The Cape Lamb and Sandwich Bluff geological units of the Lopez de Bertodano Formation exhibit a mixture of marine and terrestrial deposits. From these sedimentary deposits, researchers have already recovered plesiosaur and mosasaur marine reptiles; plant-eating dinosaurs; a meat-eating dinosaur; and a variety of modern bird groups, including shorebirds, wading birds and lagoonal birds.

The Antarctic Peninsula and Patagonia represent the western-most portion of the Weddellian Paleobiogeographic Province, a region that extends from Patagonia through the Antarctic Peninsula and western Antarctica to Australia and New Zealand. Within this province lie the dispersal routes for interchanges of vertebrates among South America, Madagascar and India, and Australia.

As the result of previous work, we hypothesize that an isthmus between more northern South America and the antarctic craton served to bring typical North American terrestrial dinosaurs, such as hadrosaurs (duck-billed dinosaurs), and marsupials and marine reptiles swimming along the coast, to Antarctica in the Late Cretaceous. We also believe this region has served as the cradle for the evolution - if not the origin - of groups of modern birds and the evolution of a suite of typical southern hemisphere plants.

To confirm and expand upon these hypotheses, we plan to continue investigations into the latest Cretaceous deposits of this area; these studies in vertebrate paleontology will be conducted in collaboration with investigators from the Argentine Antarctic Institute (Instituto Antartico Argentino). During January 2002 and 2003, we will undertake fieldwork to recover new specimens to test biogeographic and evolutionary hypotheses concerning Late Cretaceous vertebrates in Gondwana, exploring the eastern slopes of Cape Lamb, Sandwich

Bluff and False Island Point on Vega Island, and the Santa Marta Cove area of James Ross Island.

We expect this work to uncover important new insights about the evolution and geographic dispersal of several vertebrate species in particular; such results should also provide data important to understanding the development and evolution of life on Earth. (GO-061-O)

Global climate change and evolutionary ecology of antarctic mollusks in the Late Eocene.
Richard B. Aronson, Dauphin Island Sea Lab

The Eocene epoch ran from about 55 to 35 million years ago, when evidence suggests that global climate change had an important influence in Antarctica. Formerly cool-temperate conditions in the region began to shift to the polar climate that has persisted until now. As temperatures dropped, shallow-water, antarctic marine communities began to change, and these effects are still evident in the peculiar ecological relationships observed among species living in modern antarctic communities.

In particular this Late Eocene cooling reduced the abundance of fish and crabs, which in turn reduced skeleton-crushing predation on invertebrates. Thus dense populations of ophiuroids (brittlestars) and crinoids (sea lilies) began to appear in shallow-water settings. These low-predation communities appear as dense fossil echinoderm assemblages in the upper portion of the Late Eocene La Meseta Formation on Seymour Island, off the Antarctic Peninsula. Dense ophiuroid and crinoid populations remain common in shallow-water habitats in Antarctica today, but at temperate and tropical latitudes they have generally been eliminated by predators. The persistence in Antarctica of these populations is an important ecological legacy of climatic cooling in the Eocene.

For the antarctic ophiuroids and crinoids, the influence of declining predation is now well documented; but the effects of cooling on the more abundant mollusks have not been investigated. Our project will examine the evolutionary ecology of gastropods (snails) and bivalves (clams) in this same Late Eocene time frame. Based on the predicted responses of mollusks to declining temperature and changing levels of predation, we will test a series of hypotheses in the La Meseta Formation on Seymour Island. The shapes of gastropod shells, the activities of gastropods that prey on other mollusks by drilling holes in their shells, and the effects of predation on the thickness of mollusk shells should have changed significantly through Late Eocene time.

Since Seymour Island contains the only antarctic fossil outcrops readily accessible from this crucial period in Earth's history, such investigations provide a unique opportunity to learn how climate change may have affected antarctic marine communities. In practical terms, models suggest that global climate change - over the next few decades to centuries - is predicted to increase upwelling in some temperate coastal regions, which would lower water temperatures. Recent ecological evidence suggests this could lower predation in those areas. Our model of the La Meseta faunas' response to global cooling in the late Eocene should enhance understanding of the dynamic structure of modern benthic communities. (GO-065-O)

Dry valleys seismograph project.
Carl Mulcahy, U.S. Geological Survey; and Martin Dougherty, Science Applications International Corporation.

One recurrent issue in seismography is noise; that is, background phenomena that can interfere with clear and precise readings. The Dry Valleys Seismograph Project - a cooperative undertaking with the New Zealand Antarctic Program - was established to record broadband, high-dynamic-range, digital seismic data from the remote Wright Valley, a site removed from the environmental and anthropogenic noise that is ubiquitous on Ross Island.

The Wright Valley site provides one of the few locations on the continent with direct access to bedrock. The station there consists of a triaxial broadband borehole seismometer [100 meters (m) deep] and a vertical short-period instrument at 30 m. The seismological data are digitized at the remote location, telemetered by repeaters on Mount Newell and Crater Hill, and received eventually by the recording computer at the Hatherton Laboratory at Scott Base, where a backup archive is created.

These data will eventually reach the international seismological community; from Hatherton they pass along a point-to-point protocol link to the Internet at McMurdo Station and thence to the Albuquerque Seismological Laboratory for general distribution. This data set has beautifully complemented the data from other seismic stations operated by the Albuquerque Seismological Laboratory at Amundsen-Scott South Pole Station, Palmer Station, and Casey, an Australian base. (GO-078-O)

Mount Erebus Volcano Observatory: Gas emissions and seismic studies.
Philip R. Kyle and Richard C. Aster, New Mexico Institute of Mining & Technology.

Mount Erebus on Ross Island is Antarctica's most active volcano; also the only one with a persistent convecting lake of molten, alkali-rich phonolitic magma in its summit crater. This makes Erebus one of the few volcanoes on Earth with nearly continuous, small explosive activity and continuous internal earthquake (seismic) activity. As such, it provides the ideal natural laboratory to study certain phenomena; especially how gas is given off by magma, and the seismic activity that results from a convecting magma conduit.

This project entails a combination of seismic studies and gas emission rate measurements, designed to elucidate the nature and dynamics of the magmatic plumbing system, as well as eruptions and degassing from the lava lake.

The gas studies will provide some of the first data available on carbon-dioxide degassing from a highly alkalic magma system. They should also help to evaluate how much lead from Mount Erebus (relative to lead released by marine aerosols) gets into the snow on the East Antarctic Ice Sheet and thus shed light on hypotheses about the anthropogenic origins of lead. Further goals of the gas studies are to:

• examine the role of Erebus as a source of gas and aerosols to the antarctic environment;

• understand the role of volcanism as a source of carbon-dioxide emissions to the atmosphere, especially for a highly alkalic magma;

• understand the evolution of the main volatile substances (water vapor, carbon-dioxide, total sulfur, fluorine and chlorine) in the Erebus magmatic system, as well as their role in the eruptive behavior of Erebus; and

• correlate the nature of the gas emissions with the observed seismic activity.

The seismic studies of the volcano will add a permanent broadband seismic station to the array and update the present data acquisition system. We also plan to expand development of the current software to register automatic and precise timing of when and where earthquakes occur.

Deformation studies to monitor the movement of magma inside the volcano will be made, using GPS campaign-style geodetic measurements, supplemented by an array of permanent continuous operating GPS stations. During the 2001-2002 field season, we will maintain and repair the equipment - a video camera, wind generators, permanent GPS stations, a broadband seismometer, environmental sensors and power supplies installed near the summit of Mount Erebus last year.

Field-based observations will include measuring emission rates of carbon dioxide, sulfur dioxide, radionuclides, trace gases, and metals. We will use these data to evaluate the potential impact of gas emission from Erebus on the snow chemistry of the East Antarctic Ice Sheet. To study volatile zoning in the magma chamber supplying the lava lake, we will also examine short-term variations in the emission rates of fluoride, chloride, sulfur dioxide, and metals. We plan to re-occupy a GPS network on the flanks and summit of the volcano to examine any deformation that may have occurred. Finally, we will install a continuously operating GPS station at Abbott Peak.

The resultant data should enhance the collection of earthquakes that we are using in a computer model of the interior of the volcano, as well as provide a tool scientists can use for volcano surveillance, eruption monitoring, and for detecting subtle changes in the internal behavior of volcanoes. The broadband data will support a detailed study of the explosion mechanism, especially the very-long-period signals they emit. It should also help us detect temporal and spatial variability in earthquake mechanisms, which in turn might provide more insights into how variations in gas emissions may be implicated. (GO-081-O)

Late Pleistocene to Holocene Glacial History of West Antarctica.
John Anderson, Rice University.

The system of continental shelves in Antarctica reflects a diverse glaciomarine geology. Scientists hypothesize that the glacial systems of the Antarctic Peninsula - having smaller ice masses, at a more northerly location - have been more responsive to climate change and sea-level rise than either the West Antarctic or East Antarctic Ice Sheets. Currently, some of the Antarctic Peninsula ice shelves are retreating as fast as 1 kilometer per year. But the key questions have by no means been settled - Why are these systems behaving so differently? And, are the changes due to recent atmospheric warming in the region, or are they simply the final phase of retreat since the last glacial maximum?

To contribute to this debate, we are testing a hypothesis - that the history of glacial retreat within the Antarctic Peninsula region has been differential and quite complex, with different glacial systems retreating at different rates and at different times. It would appear that this complex recessional history reflects the different sizes, as well as different climatic and physiographic settings, of the various glacial systems in the region. To address how these systems may have responded to sea-level and climate change during the Late Pleistocene to Holocene time interval, a better glacial history is needed.

We plan to acquire new marine geological and geophysical data from the continental shelf, building on an extensive seismic data set and hundreds of sediment cores collected along the Peninsula during cruises in the 1980s. We hope to establish when different glacial systems were grounded on the shelf, the extent of grounded ice, and the larger outlines of the history of glacial retreat. Key to this investigation is the acquisition of swath bathymetry, side-scan sonar, and very-high-resolution, sub-bottom (chirp) profiles from key drainage outlets.

These new data should provide the necessary geomorphologic and stratigraphic framework to reconstruct the Antarctic Peninsula glacial record. In such a paleohistorical context, models of future glacier and ice-sheet activity should be enhanced. (GO-083-O)

A GPS program to monitor motions in the bedrock of the West Antarctic Ice Sheet.
Ian Dalziel and Frederick Taylor, Institute of Geophysics, University of Texas; Robert Smalley, University of Memphis; and Michael G. Bevis, University of Hawaii.

The bedrock that underlies the West Antarctic Ice Sheet (WAIS) is not well described. Without a reliable evaluation of its history - both tectonic and ice-induced crustal motions - we will never be able to fully comprehend the past, present and future dynamics of the WAIS. Without that knowledge, we cannot develop reliable global change scenarios for the future, nor accurately factor the antarctic region into global plate movements. Currently, permanent Global Positioning System (GPS) networks to measure bedrock movement are established only on the fringe of the WAIS; they cannot provide the data on subglacial volcanism, active tectonics, and ice streaming that are needed.

This project is focused on establishing baseline, long-term, reliable geodetic measurements of the crustal motion in the bedrock beneath the WAIS. To obtain them, we will build a West Antarctica GPS Network (WAGN) of at least 15 GPS sites across the west antarctic interior - an area comparable to that from the Rocky Mountains to the Pacific coast - over 2 years beginning in the 2001-2002 austral summer.

This first summer, we will initiate the WAGN network and test precision and velocities at the most critical sites. The embryonic network will begin to fill a major gap in GPS coverage by looking for potential bedrock movements. If crustal motions are relatively slow, meaningful results will only begin to emerge over the next 5 years or so. Once it is permanently established, however, the network should yield increasingly meaningful results with the passage of time. Indeed, the slower the rates turn out to be, the more important it is to start measuring early.

WAIS bedrock is so scattered and remote that to erect a continuous string of permanent GPS stations would rival the building of the American transcontinental railroad. Instead, we plan to follow the Multi-modal Occupation Strategy (MOST). This entails "roving" receivers (based in permanent monuments set in solid rock outcrops) in place for only a short time at each site, providing data that can be ranged against permanent GPS readings elsewhere. Each of these "bases" can be converted in the future to a permanent, autonomous station when more logistics and satellite data linkage throughout West Antarctica are in place. When detectable motions occur, we can reoccupy the most critical sites, obtain more reliable velocities, and make decisions about reoccupying the entire network.

We expect the results of this project to establish important early indicators of crustal plate dynamics beneath the WAIS. As scientists take these into account in refining their models, future measurements and a time-series of the geodetic data should gradually produce a more constrained picture of WAIS subglacial dynamics; that is, plate rotations and both elastic and viscoelastic motions caused by deglaciation and ice-mass changes. (GO-087-O)

TAMSEIS: A broadband seismic experiment to investigate deep continental structure across the east-west antarctic boundary.
Douglas Wiens, Washington University.

Antarctica's outline shape looks generally like Australia, though half again as large; but beneath its enormous ice sheet lies evidence of its origin. East Antarctica has a bedrock continent-like foundation, while the ice sheet over West Antarctica - a third the area - in fact covers a series of "islands." West Antarctica shares a geologic history with the South American Andes Mountains, the result of plates colliding and subducting. East Antarctica is more like a large coherent chunk that broke free of the supercontinent Gondwanaland and drifted to a new position at the bottom of the world. The boundary between these two regions (with their disparate geologic pedigrees) is called the east-west antarctic boundary, and the crust and upper mantle here reveals many important and interesting distinctions, which tells the basic story of the tectonic development of Antarctica.

In November 2000 we began making seismic measurements - using three different arrays and a total of 44 seismic stations - all geared to evaluating geodynamic models of the evolution of Antarctica that rely on data about the crust and upper mantle. To analyze the data, we will use a variety of proven modeling techniques, including body- and surface-wave tomography, receiver function inversion, and shear-wave splitting analysis.

One basic question is, How were the Transantarctic Mountains formed? Though widely considered a classic example of rift-flank uplift, there is little consensus about the exact uplift mechanism. Many theories have been proposed, ranging from delayed phase changes to transform-flank uplift. All of these make various assumptions about upper mantle structure beneath and adjacent to the rift-side of the mountain front.

Another focus will be the structure of the east antarctic craton, the highest ice block in the world. Was this anomalous elevation a prime driver in the onset of glaciation there? More to the point, how did it arise? Proposed models include isostatic uplift from thickened crust, anomalously depleted upper mantle, and thermally modified upper mantle, as well as dynamic uplift. How far the old continental lithosphere extends is also uncertain. In particular, it is unknown whether the old lithosphere extends to the western edge of East Antarctica beneath the crustal rocks deformed during the Ross Orogeny (formation).

When completed and analyzed, this comprehensive set of data and theory testing will enable new maps of the variation in crustal thickness, upper mantle structure, anisotropy, and mantle discontinuity topography across the boundary of East and West Antarctica, providing a much enhanced foundation for understanding the geodynamics of the antarctic. (GO-089-O)

Logistics support for global seismographic network stations at the Amundsen-Scott South Pole and Palmer stations.

Rhett Butler, Incorporated Research Institution for Seismology.

Seismology, perhaps as much as any other science, is a global enterprise. Seismic waves resulting from earthquakes and other events can only be interpreted through simultaneous measurements at strategic points all over the planet. The measurement and analysis of these seismic waves are not only fundamental for the study of the earthquakes, but also serve as the primary data source for the study of the Earth's interior. To help establish the facilities required for this crucial scientific mission, IRIS (the Incorporated Research Institution for Seismology) was created in 1985.

IRIS is a consortium of universities with research and educational programs in seismology. Ninety-seven universities are currently members, including nearly all U.S. universities that run seismological research programs. Since 1986, IRIS (through a cooperative agreement with the National Science Foundation (NSF) and in cooperation with the U.S. Geological Survey) has developed and installed the Global Seismographic Network (GSN). The GSN now has about about 135 broadband, digital, high-dynamic-range, seismographic stations around the world, all with real-time communications.

The GSN seismic equipment at Amundsen-Scott South Pole Station and at Palmer Station, Antarctica, was installed jointly by IRIS and ISGS, who together continue to operate and maintain them. The GSN sites in Antarctica are vital to seismic studies of Antarctica and the Southern Hemisphere. The state-of-the-art seismic instrumentation is an intrinsic component of the NSF effort to advance seismology and Earth science globally. (GO-090-P and GO-090-S)

Development of a luminescence dating capability for antarctic glaciomarine sediments: Tests of signal zeroing in the Antarctic Peninsula.

Glenn Berger, Desert Research Institute, and Eugene Domack, Hamilton College.

Paleoclimatology - the study and reconstruction of ancient weather, climate and their likely effects - is not an exact science. Climatic indicators, such as marine sediments that have been abundantly deposited over the last 2 million years surrounding Antarctica, provide useful information about such phenomena as the waxing and waning of ice sheets - but only to the extent that these fossils can be accurately dated.

Traditionally, radiocarbon dating with the naturally occurring isotope ^{14}C has proved reliable for specimens as old as 40,000 years, perhaps even up to 70,000 years, though problems such as the "reservoir effect" can also limit its reliability and range. However, increasing amounts of ^{14}C in the atmosphere have compromised its precision. A more recently developed method, photon-stimulated-luminescence sediment dating (photonic dating) has been used in temperate latitudes for eolian and waterlain deposits and proved reliable over a larger span of Quarternary time - from decades to hundreds of thousands of years. The question has yet to be answered, however - can this method be reliably used in polar regions?

Marine sediments in and around Antarctica pose special difficulty because polar onditions can limit the sunlight that detrital grains are exposed to. Since the thermoluminescent test involves reflecting the last time a sample was exposed to light (what is known as the clock-zeroing process), antarctic glaciomarine depositional settings and processes could undermine the potential reliability of photonic dating of antarctic marine sediments, and ages could be overestimated if grains were not exposed to daylight before deposition. Other processes could also compromise photonic dating. For example, transport of terrigenous suspensions by neutrally buoyant "cold-tongue" (mid-water) plumes may be common around Antarctica, yet the effect of such transport on luminescence zeroing is unknown. Typical marine cores taken near Antarctica may contain an unknown fraction of detrital grains from cold-tongue and near-bottom suspensions.

In this project, we will collect detrital grains from a variety of "zero-age" (modern) marine depositional settings within the Antarctic Peninsula, where representative antarctic depositional processes have been documented and where logistics permit access.

By systematically studying the effectiveness of luminescence-clock-zeroing in antarctic glaciomarine settings we hope to determine whether photonic dating can be reliably applied to antarctic marine sediments in the future. In the process, we expect to develop refined sedimentological criteria for selecting future samples. If we can validate photonic-dating in this environment, scientists would gain a numeric geochronometer extending well beyond the age range of ^{14}C dating, and be better able to answer a number of broader questions about the timing and extent of past glaciations near and on the antarctic shelves. (GO-092-O)

Permian-Triassic basin history of southern Victoria Land and the Darwin Mountains.
John Isbell, University of Wisconsin.

The Earth is believed to have once consisted of a single land mass, a supercontinent called Pangea, composed of all the continental crust that now makes up the various continental and island surfaces. As tectonic forces began to break up the land mass about 150 million years ago, Gondwanaland was born (as was Laurasia); its southern portion would eventually become Antarctica. Before this split, around 250 million years ago, geologic features extended across what would become separate continents. One of the largest depositional basins was the "Gondwanide foredeep," more than 10,000 kilometers long, extending across the land that would become southern South America, South Africa, the Falkland Islands, Antarctica, and Australia.

Antarctica's central location in this ancient assemblage, between South Africa and Australia, make southern Victoria Land and the Darwin Mountains key areas for testing paleogeographic and paleoclimatic models. Such work will further constrain the paleoenvironmental, tectonic, biotic, and paleogeographic histories of southern Pangea, and provide a unique polar view of the world during an icehouse-to-greenhouse transition.

Our project is a collaborative sedimentological, palynological, and paleomagnetic study of Permian and Lower Triassic strata in these areas. We will recover paleomagnetic signatures from Permian and Triassic petrified wood, silicified peat, and coal, which were cemented during early diagenesis (the process of undergoing chemical, bioilogical and physical change until metamorphism is reached). Paleopalynological analyses - the study of fossilized microscopic organisms - will provide time control for the succession.

We hope to be able to:

• determine a Late Paleozoic (as Gondwanaland drifted over the South Pole) glacial/deglaciation history for southern Victoria Land and the Darwin Mountains,

• document Permian strata to better understand the environments of high-latitude fluvial coal-bearing deposits,

• document Triassic lithofacies to better understand high-latitude conditions during the Early-to-Middle Triassic "coal gap" interval,

• provide a well-constrained stratigraphic framework for the Permian-to-Lower Triassic succession,

• test the diachronous and inversion tectonic models for the Panthalassan Margin of southwestern Pangea, and

• construct better paleogeographic models for Gondwanaland by obtaining new Gondwanaland reference poles for the Permian and Triassic. (GO-094-O)

Acquisition and operation of broadband seismograph equipment at Chilean bases in the Antarctic Peninsula region.
Douglas Wiens and Gideon P. Smith, Washington University.

The present-day tectonics and seismological structure of the Antarctic Peninsula and Scotia Plate region are among the most poorly understood of any location in the world. This region offers a unique and complex geodynamic setting, as illustrated by recent changes in the pattern of volcanism and other tectonic activity. We constitute the U.S. component of an international effort, using a large-scale deployment of broadband seismographs to study the seismotectonics and seismic structure of these regions.

During the 1996-97 field season, broadband seismographs were installed at strategic locations; one on the tip of South America and three more in the South Shetland Islands and on the Antarctic Peninsula. In succeeding years, seven more were added to the network, which has yielded excellent data and some suggestive early results. As the project continues, cumulative data should enhance understanding of the seismicity of the South Shetland Trench, an unusual subduction zone where young lithosphere is subducting very slowly.

The continuing collaboration between Washington University and the Universidad de Chile will contribute important seismological data to the Incorporated Research Institution for Seismology (IRIS) data center, as well as to other international seismological collaborators. Such mutual exchanges with other national antarctic seismology research programs will accumulate data from a variety of other proprietary broadband stations in the region.

These data will support seismic studies of the upper mantle velocity structure of several complicated tectonic regions in the area, including the South Shetland subduction zone, the Bransfield backarc rift, and diffuse plate boundaries in the areas around Patagonia, the Drake Passage, and along the South Scotia Ridge. Such studies should provide important constraints on the crustal structure beneath the stations; in turn improved structural models will help to pinpoint better locations for future instruments. (GO-97-O)

Neogene-Quaternary volcanic alignments in the Transantarctic Mountains-Ross Sea region.
Terry J. Wilson, Ohio State University.

Plate tectonics has become the reigning paradigm to explain both the evolution and the current dynamics of the Earth. But in addition to the more dramatic movement of the Earth's crustal plates, the crust also contains buoyancy forces that contribute to basic calculations, and distinguishing between these and plate boundary forces is important. The "Antarctic Stress Map Project" (ASMAP) initially will obtain data on these forces from Neogene/Quaternary volcanic vent alignments within the Transantarctic Mountains and adjacent West Antarctic rift system in the Ross Sea region.

We will map the distribution, alignments, and morphologies of volcanic cones and other volcanic features using high-resolution satellite imagery (for example, SPOT and SAR) and aerial photographs. Field tests will assess any structural associations that we can find between faults and volcanic vent alignments. These data will be coupled with existing chronological and petrological information on the volcanic rocks, as well as other dike and fault data, to interpret alignments and to define neotectonic stress states throughout this sector of Antarctica.

We will be able to analyze the stress regime in the context of other ongoing studies of contemporary tectonics and paleo-kinematics of the Transantarctic Mountains rift flank and adjacent rift system. This new stress field data, derived from the unique antarctic setting, will help to constrain the role of plate-boundary and crustal buoyancy forces in actively deforming intraplate regions. (GO-099-O)

Relative frequency and phase of extreme expansions of the antarctic ice sheets during the late Neogene.
Phillip Bart, Louisiana State University.

Expansions and contractions of the antarctic ice sheets (AISs) have undoubtedly had a profound influence on Earth's climate and global sea level. But the cryosphere in Antarctica is not a single homogenous entity. Science has yet to embrace its three primary components - the East Antarctic Ice Sheet (EAIS), the West Antarctic Ice Sheet (WAIS), and the Antarctic Peninsula Ice Cap (APIC) - into a unified theory. Among these systems may be found differences in ice volume, substratum elevation, ice-surface elevation, and latitude.

Various lines of evidence do show, however, that the extent of ice in all three ice sheets has undergone significant retreats and advances; future episodes appear inevitable. But exactly how and why the ice has fluctuated so is not certain. According to one line of reasoning, the land-based EAIS has been relatively stable, experiencing only minor fluctuations since forming in the middle Miocene; by contrast, the marine-based WAIS has been dynamic, waxing and waning frequently since the late Miocene. A conflicting hypothesis has the ice sheets advancing and retreating at about the same time.

Building on previous seismic-stratigraphic investigations of the continental shelves, we will use high-resolution seismic technology to focus on the frequency and phase of extreme advances of the ice sheets to the continental shelf. The data suggest a couple of useful scientific inquiries:

First, Did extreme advances of the EAIS and WAIS occur across the shelf occur at about the same times and frequencies? This evaluation is possible because the EAIS drains into the western Ross Sea continental shelf (Northern Basin), while the WAIS drains into the eastern Ross Sea (Eastern Basin). Existing regional grids of high-resolution seismic data have been collected, but these are incomplete and cannot be used to determine the stratigraphic correlations from the Northern Basin to the Eastern Basin. We plan to collect high-resolution seismic data (approximately 2,000 line-kilometers) to address this issue.

Second, Did the APIC advance frequently across the shelf? Some investigators have inferred that the APIC advanced across the continental shelf at least 30 times since the middle Miocene. If true, that activity would be an order of magnitude more frequent than advances of the EAIS and WAIS. Others interpret the seismic reflections differently and argue that the advances of the APIC were far fewer. The existing high-resolution seismic grids from the Antarctic Peninsula contain only one regional strike line on the outer continental shelf; we plan to collect high-resolution seismic data (approximately 1,000 line-kilometers) during a January 2002 cruise to the Antarctic Peninsula.

As part of this project, we are integrating our research into a graduate-level course at Louisiana State University and are also developing a pilot outreach program with a Baton Rouge public high school. Responding to scientific standards the Louisiana Department of Education has recently adopted to reflect what ninth through twelfth grade students should be able to do and learn, we are framing an experience to convey the excitement of conducting scientific research as a way to encourage them to pursue earth science at the university level. (GO-154-O)

Advanced Technology for radar sounding of polar ice.
David Morse, University of Texas, Austin

Since its inception in the late 1960's, radar sounding has distinguished itself as perhaps the single most important technique for glaciological work and constitutes a tool in the arsenal of sub-ice geological research. In the 1970s, the Technical University of Denmark (TUD) designed and constructed an ice-penetrating radar based on then state-of-the-art technology. This venerable system has collected the vast majority of all ice-sounding data from the ice sheets of Antarctica and Greenland. During the 1990s, an upgraded digital version of this same radar system (UT/TUD, developed by the University of Texas) was used for extensive ice-thickness-resolution surveys in both West and East Antarctica.

But terrestrial glaciology isn't the only beneficiary of advanced digital radar. Recent interest in the Martian paeleoenvironment and the recognition of possible ice-covered oceans on the Jovian satellites has stimulated research activity in sub-ice detection and characterization problems. One result has been the development of a prototype for an ice-penetrating radar that is a test-bed for sounding of planetary ice bodies. Developed by the Jet Propulsion Laboratory and constructed with the assistance of the University of Kansas, field tests indicate this new radar could help address fundamental questions at the forefront of glacio-geophysical research. Preliminary field tests, however, have revealed some limitations with the current prototype.

To achieve scientific progress on several problems at the forefront of glaciological and glacio-geophysical research, an improved system of radar ice sounding is needed. This project is focused on overcoming these shortcomings by merging components of the JPL/KU radar with the UT/TUD radar into a new "Multi-Institutional Radar Sounder" (MIRS). Targeted improvements are:

• improved ice-column penetration to detect the subglacial interface through thick and/or warm ice, as well as through highly heterogeneous ice;

• improved internal-layer spatial resolution and improved deep-layer detection; and

• the ability to characterize the subglacial interface and, specifically, to identify the presence of water.

We expect MIRS to:

• improve layer resolution and total system sensitivity through pulse compression (relative to the current UT/TUD radar);

• characterize the detected interfaces for material/roughness by preserving the complete shape (both magnitude and phase) of the echo waveform, even as it automatically calibrates the overall system sensitivity; and

• "see through" highly scattered ice - such as the crevassed regions near ice-stream margins or in valley glaciers - in a more powerful way.

We plan field tests that target a wide range of ice-sheet environments, including both hypothesized and established subglacial water bodies underlying the thickest portions of the East Antarctic Ice Sheet during a series of airborne radar surveys to be conducted in the 2001-2002 austral summer. We hope to verify system design and fully establish the capabilities of the MIRS. (GO-167-O)

A target for high-resolution Quaternary and older environmental change records: Site survey for drilling the Mackay Sea Valley, Western Ross Sea.
Ross Powell, Northern Illinois University

Paleoecology is an effort to reconstruct past environments - including the relationships of the biota that inhabited them - as comprehensively as possible. Scientists have been able to develop fairly high-resolution records of environmental change during the last 1.6 million years (the Quarternary). These studies and models provide a rational basis for predicting the future, and distinguishing natural variability from human-induced changes. We hope to extend the database of high-resolution marine geological records of environmental change that have been established in Antarctica, addressing Quaternary and perhaps even older environmental changes.

We will begin with a detailed site survey of the Mackay Sea Valley (MSV), collecting information to locate the best drill sites, as well as data to help engineers evaluate the drilling and coring systems that will take later samples. MSV extends through Granite Harbor and out to the western Ross Sea, and was formed by erosion associated with early Cenozoic expansion of Mackay Glacier, a major outlet glacier of the East Antarctic Ice Sheet. The valley then began to accumulate sediments, the record of which extends back through the Quaternary and possibly into earlier Late Cenozoic times.

Coring sites in the MSV are excellent targets because:

• they possess the highest resolution record of Quaternary marine environmental change known in the Ross Sea sector, probably due to their great water depth and near shore location, as well as the polar climate;

• the sedimentation regime is one of the most intensely studied coastal settings in Antarctica;

• a preliminary geophysical site survey exists; and

• the sediments appear to have the potential for good chronological control (based on previous piston core work).

These characteristics should enable us to gather high-quality site survey information. This austral summer we hope to provide the data needed for a full assessment of the site's potential for high-resolution records of environmental change in the MSV. If the site yields quality data, we hope eventually to:

• extract a high-resolution (decades to centuries) scale of the Quaternary in the McMurdo Sound area, using multi-proxy techniques;

• correlate the marine-terrestrial data with geological and ice-core records both from local sites and elsewhere in Antarctica (for example, the Dry Valleys and Antarctic Peninsula Quaternary geological records, and the Taylor and Siple Dome ice core records);

• test antarctic variability, using records from the Northern Hemisphere to make cross-hemispheric comparisons;

• determine the age of MSV unconformity - which may well reflect glacial cutting within the MSV by the Mackay Glacier during past Quaternary expansion(s) - and provide constraints on Neogene erosion rates; and

• characterize older Quaternary and/or Neogene(?) sediment below the unconformity, which could potentially provide information on the Pliocene history of the area. (GO-170-O)

Antarctic network of unattended broadband integrated seismometers (ANUBIS).
Sridhar Anandakrishnan, University of Alabama.

Despite much attention in recent years, the structure and dynamics of the antarctic crust and the composition and geometry of the mantle are still poorly understood. Seismology remains the primary method for studying these structures, as well as processes in the Earth's deeper asthenosphere, but Antarctica lags behind in the effort to improve global seismic imaging and tomography. On this huge continent, there are only eight broadband seismic observatories. Except for the installation at South Pole, those stations are along the margins of the continent and none are in West Antarctica. By contrast, there are 200 permanent stations worldwide in the Federation of Digital Seismograph Networks (FDSN), and some 1,000 more, in national networks not yet integrated into the FDSN.

We have developed a passive seismic network of 11 long-term broadband seismic stations on the continent itself. Because 98 percent of the continent is ice covered, these stations will be installed at the surface of the ice sheet. The body-wave data thus recorded from regional and teleseismic earthquakes can be analyzed at each station for local crustal thickness, lamination, Poisson's ratio (a measure of crustal composition), crust and mantle anisotropy (a measure of current and former stress regimes), and identification of rift zones and crustal block boundaries. In addition, the data from all stations (including the existing peripheral ones) can be used for seismic tomographic analysis to detail lateral variations in these properties.

This year we will remove all of the stations and return the equipment to the United States. (GO-180-O)

Aeolian processes in the McMurdo Dry Valleys, Antarctica.
Nicholas Lancaster, Desert Research Institute.

The McMurdo Dry Valleys provide a unique natural laboratory where scientists can study some fundamental processes in nature. Geomorphology, for example, is the study of landforms and the processes that shape them; for example, particles (sand, dust, snow, etc.) blown by the wind across a characteristic terrain. Wind-shear-stress partitioning analysis can create models to predict how such wind-borne particles, en route to a surface, may be affected by intervening elements that possess a certain roughness - boulders, in the case of the McMurdo Dry Valleys. On-going studies of such regions (that is, sparsely vegetated to unvegetated rough surfaces) should provide models relevant to other arid areas on Earth and on Mars, as well as a range of rocky desert and sand sheet sites.

Using novel instrumentation (Irwin Sensors) that was recently developed and has been tested in field and laboratory wind tunnel experiments, we will conduct studies of boundary layer winds and surface shear stress at four to six locations. This work will contribute to the testing and improvement of existing theoretical models for shear-stress partitioning. We hope the research will lead to the development of an improved and universally applicable model for estimating sediment transport by wind on surfaces that are covered by varying densities of non-erodible roughness elements. (GO-183-O)

Ferrar basaltic tuff-breccias formed by direct eruption: Evaluating a Hypothesis.
David Elliot, Ohio State University.

Gondwanaland was one of the supercontinents, part of which was destined in Mesozoic times to break off and move to the geographic south pole as Antarctica. As the land mass broke up during a major magmatic event, voluminous basaltic magmas were erupted at the surface and intrusive sills and dikes were emplaced at depth within the underlying sedimentary sequence. The record of this process in Antarctica shows extrusive rocks that include thick tuff-breccias (coarse pyroclastic rocks), believed to have formed by subsurface explosive interaction of basaltic magma and water in aquifers. This clash of media with dramatically different temperatures is known as phreatomagmatic process.

In modern rift settings, volcanic fields are commonly found, where rising magmas interact explosively with water in aquifers or at the surface. The volcanic fields in parts of Antarctica, however, are unique. Compared to other well-documented examples, these basaltic pyroclastic rocks differ in terms of areal extent and thickness of deposits, depth of magma/water interaction, and dominance of basaltic tuff-breccia. We expect study of the paleovolcanology of these rocks to yield important new information on the origins and emplacement mechanisms of tuff-breccia deposits, as well as and on the evolution of volcanic fields in which tuff-breccias form a significant component.

To better describe the processes involved in forming these exceptionally thick tuff-breccias, we hope to:

• document the three-dimensional architecture of the basaltic pyroclastic rocks;

• establish the depth of magma/water interaction; evaluate aquifer recharge;

• establish the nature and extent of the volcanic field and its paleovolcanologic setting; and

• evaluate the hypothesis that these tuff-breccias are the result of direct eruption from volcanic vents.

Building on reconnaissance work, we expect the results of this study to have broad implications for understanding how phreatomagmatic processes form tuff-breccias, and the tectonic settings in which it occurs. Results are also expected to develop the paleovolcanologic setting of the Transantarctic Mountains during the Jurassic. (GO-290-O)

High precision GPS survey support.
Bjorn Johns, University NAVSTAR Consortium (UNAVCO).

UNAVCO provides year-round support for scientific applications of the Global Positioning System (GPS) to U.S. Antarctic Program, supported and managed by the National Science Foundation's Office of Polar Programs. This support includes pre-season planning, field support, and post-season follow-up, as well as development work for supporting new applications. UNAVCO maintains a "satellite" facility at McMurdo Station during the austral summer research season, providing a full range of support services; including geodetic GPS equipment, training, project planning, field support, technical consultation, data processing, and data archiving.

UNAVCO also operates a community differential GPS (DGPS) base station that covers McMurdo Sound and Taylor Valley, provides maintenance support to the MCM4 continuous GPS station as contractual support to the

NASA GPS Global Network (GGN), and supports remote continuous GPS stations for scientific investigations.

Using GPS, vector baselines between receivers separated by 100 kilometers or more are routinely measured to within 1 centimeter (that is, 100 parts per billion). UNAVCO is also able to support researchers who are investigating global, regional, and local crustal motions where maximum accuracy (in the millimeter range) of baseline measurement is required. GPS measurements using portable equipment can be completed in a few hours or less. Such expediency lends itself to research applications in global plate tectonics, earthquake mechanics, volcano monitoring, and regional tectonics. (GO-295-O)

Chemical weathering in Taylor Valley streams: Sources, mechanisms, and global implications.
W. Berry Lyons, Ohio State University, and Brent McKee, Tulane University.

Geochemists study the process of "chemical weathering" - whereby rocks and minerals are transformed into new, fairly stable chemical combinations, primarily by such chemical reactions as oxidation, hydrolysis, ion exchange and solution. Silicate hydrolysis is another such process, which may have an impact on the global climate by consuming carbon dioxide (CO_2), an important greenhouse gas. Generally scientists have concentrated on more temperate climates to examine chemical weathering, because two of its most significant drivers are warmth and humidity.

However, recent data suggests that chemical weathering can and does occur in polar desert streams. At around 78°S, a number of ephemeral streams in Taylor Valley, Antarctica, that are associated with dry-based glaciers flow for 4 to 10 weeks each year. Solutes produced from chemical weathering such as major cations, minor elements (for example, rubidium, cesium, lithium, strontium, and barium), bicarbonate, and dissolved reactive silica, as well as isotopes ($^{87}Sr/^{86}Sr$) have been found here. Although the mechanism/process of weathering is unknown, we hypothesize that the high chemical weathering rates that have been computed derive either from the high coincidence of freezing/thawing cycles and/or the unusual hydrologic behavior of the hyporheic zone in these streams.

Building on the initial work of the McMurdo Dry Valleys Long Term Ecological Research team and others, we hope to better establish weathering rates and weathering mechanisms by examining the cryogenic processes whereby physical weathering may influence chemical weathering. To establish what materials are being weathered, we will analyze the suspended matter (in streams from the Lake Bonney basin in Taylor Valley and the Onyx Valley in Wright Valley) for their bulk chemistry and then compare these data to rock types in the valleys. To better ascertain solute sources, we will focus on uranium series geochemistry. Using major rock types from the Taylor and Wright valleys, we will also conduct laboratory experiments to establish how microfracturing from freeze-thaw cycles may affect chemical weathering.

All of the data will be used to draw analogies to historic weathering regimes on Earth during colder, drier, climatic eras.

Seismic and stratigraphic data acquisition and integration for Cenozoic tectonic and paleoenvironmental analysis in McMurdo Sound.
David Harwood, University of Nebraska, Lincoln.

Because it is perenially covered by ice, Antarctica presents a challenge to geologists looking back to Cenozoic times - strata of that age are accessible primarily through drill cores. To resolve the depositional context of the soil and to select the best potential drill sites, good seismic data are necessary.

Over the last 20 years of drilling experience, much has been learned through such projects as the Deep Sea

Drilling Project (DSDP), Ocean Drilling Project (ODP) and via the fast-ice and on-land drilling of the Dry Valley Drilling Project (DVDP), McMurdo Sound Sediment and Tectonic Studies (MSSTS), Cenozoic Investigations of the Ross Sea (CIROS) and Cape Roberts Project drill holes. ANDRILL, the latest international drilling effort, has just begun.

This project includes a geological field team sponsored by Antarctica New Zealand (the New Zealand national antarctic program) and the Institute of Geophysical and Nuclear Sciences of New Zealand. The American component of the team will focus on the McMurdo Sound area, using drilling technology proven in the Cape Roberts Project. During the 2001-2002 austral summer, we will survey sites in the three ANDRILL target areas and collect new seismic information to address tectonic, basin history, and paleoenvironmental questions. Each country will be responsible for acquiring seismic data in specific target areas - United States in the New Harbor region, New Zealand at Windless Bight, and the United Kingdom on the southern end of the McMurdo Ice Shelf.

Beyond the requisite site survey work, the seismic data should help address questions regarding:

• the geometry of sedimentary sequences, which should provide insight on competing theories of the development of the Victoria Land Basin, as well the uplift history and possible causes of the adjacent Transantarctic Mountains;

• the contrasting stratigraphic history recorded in the Ferrar and Taylor valleys; and

• whether the McMurdo Dry Valleys landscape has experienced a stable cold, polar climate for the last 20 million years.

The new seismic information will also put existing drill core data into a broader stratigraphic framework. The spirit of international collaboration developed through the Cape Roberts Project and continuing with ANDRILL will result in scientific exchange during the follow-up studies of all three target areas. The 12 drill holes already established in the McMurdo Sound/Dry Valleys region, combined with new seismic data to be acquired (by this project, from research ships and from future drill holes) will make this region a nexus for correlating future chronostratigraphic data on the antarctic continental shelf.